

Claims

- [c1] A microplasma emission spectrometer comprising:
a chamber for confining a sample volume of gas, the chamber having an exit aperture and a window that passes optical emission;
a microplasma source having a resonant antenna structure that is positioned proximate to the chamber, the resonant antenna structure generating a microplasma in the chamber from the sample volume of gas;
a RF power supply that is electrically coupled to the resonant antenna structure, the RF power supply providing power to the resonant antenna structure that generates the microplasma from the sample volume of gas; and
a spectrally sensitive detector having an entrance that is optically coupled to the microplasma, the entrance having dimensions and being positioned so that emissions from at least one-tenth of a total volume of the microplasma are transmitted through the entrance of the spectrally sensitive detector.
- [c2] The spectrometer of claim 1 wherein the microplasma source is formed on a planar substrate.
- [c3] The spectrometer of claim 2 wherein the planar sub-

strate is chosen from the group comprising glass, sapphire, quartz, aluminum nitride, alumina, fused silica, fiberglass, fiber reinforced epoxy, FR-4, Teflon (PTFE), delrin, polyimide, ceramics, and ceramic/polymer composites.

[c4] The spectrometer of claim 2 wherein the microplasma source is fabricated monolithically on the planar substrate.

[c5] The spectrometer of claim 2 further comprising a discrete electrical element that is attached to the planar substrate.

[c6] The spectrometer of claim 1 wherein the entrance of the spectrally sensitive detector has dimensions and is positioned so that emissions from at least one-quarter of a total volume of the microplasma are transmitted through the entrance of the spectrally sensitive detector.

[c7] The spectrometer of claim 1 wherein the entrance of the spectrally sensitive detector is butt coupled to the window.

[c8] The spectrometer of claim 1 wherein the microplasma source generates a microplasma having a plasma sheath volume-to-total plasma volume ratio that is greater than about 0.1.

- [c9] The spectrometer of claim 1 wherein the power provided by the RF power supply is less than about 20W and a power density of the microplasma is greater than about $0.5\text{W}/\text{cm}^3$.
- [c10] The spectrometer of claim 1 wherein the resonant antenna structure is driven at a frequency that is in the range of 100–1,500MHz.
- [c11] The spectrometer of claim 1 wherein the resonant antenna structure comprises a spiral antenna structure.
- [c12] The spectrometer of claim 1 wherein the resonant antenna structure is formed of a material selected from the group comprising gold, copper, platinum, aluminum, nickel, electro-less nickel, silver, tin, and solder material.
- [c13] The spectrometer of claim 1 further comprising a magnet that is positioned relative to the resonant antenna structure so that a magnetic field generated by the magnet confines electrons in the microplasma.
- [c14] The spectrometer of claim 13 wherein a magnitude of the magnetic field generated by the magnet is chosen to create an electron cyclotron resonance condition at one or more points within the chamber at a frequency of a signal provided by the RF power supply.

- [c15] The spectrometer of claim 1 wherein the spectrally sensitive detector comprises an optical spectrometer.
- [c16] The spectrometer of claim 1 further comprising an optical element that focuses emissions from the microplasma onto the entrance of the spectrally sensitive detector.
- [c17] The spectrometer of claim 1 wherein the exit aperture of the chamber has a width that is less than one mean free path of a gaseous species of interest in the microplasma.
- [c18] The spectrometer of claim 1 wherein a distance between the window and the exit aperture of the chamber is greater than about one mean free path of a gaseous species of interest in the microplasma.
- [c19] The spectrometer of claim 1 wherein an area of the exit aperture is less than about ten times an area of the window.
- [c20] A method of analyzing a gaseous environment, the method comprising:
introducing a volume of gas to be analyzed into a chamber;
generating a microplasma from the volume of gas;
imaging emissions generated within at least one-tenth

of a total volume of the microplasma onto an entrance of a spectrally sensitive detector; and
analyzing at least one spectral region of the imaged emissions to characterize the gaseous environment.

[c21] The method of claim 20 wherein the imaging comprises imaging with an optical system.

[c22] The method of claim 20 wherein the introducing the volume of gas comprises introducing a volume of gas by diffusion.

[c23] The method of claim 20 wherein the introducing the volume of gas comprises introducing a volume of gas by establishing a pressure differential between the gaseous environment and the chamber.

[c24] The method of claim 20 further comprising controlling the pressure inside the chamber.

[c25] The method of claim 20 further comprising generating a magnet field through the microplasma, the magnetic field confining electrons in the microplasma.

[c26] The method of claim 25 wherein a magnitude of the magnetic field is chosen to create an electron cyclotron resonance condition in the microplasma.

[c27] A microplasma spectrometer comprising:

a chamber for confining a sample volume of gas, the chamber having an exit aperture and a window that passes emissions;

a microplasma source that generates a microplasma from the sample volume of gas, the microplasma having a plasma sheath volume-to-total volume ratio that is approximately between about 0.1 and 0.9;

an optical element that is positioned to image emissions from the microplasma, the optical element being positioned a distance from a center of the microplasma that is less than ten times a transverse dimension of the microplasma; and

a spectrally sensitive detector coupled to the optical element.

[c28] The spectrometer of claim 27 wherein the microplasma source is formed on a planar substrate.

[c29] The spectrometer of claim 28 further comprising a discrete electrical element that is attached to the planar substrate.

[c30] The spectrometer of claim 28 wherein the microplasma source is fabricated monolithically on the planar substrate.

[c31] The spectrometer of claim 27 wherein a power con-

sumed by the microplasma source is less than about 20W.

[c32] The spectrometer of claim 27 wherein the microplasma source comprises a resonant antenna structure that is driven at a frequency in the range of about 100–1,500MHz

[c33] The spectrometer of claim 27 further comprising a magnet that is positioned relative to the microplasma source so that a magnetic field generated by the magnet confines electrons in the microplasma.

[c34] The spectrometer of claim 33 wherein a magnitude of the magnetic field generated by the magnet is chosen to create an electron cyclotron resonance condition at one or more points within the chamber.

[c35] The spectrometer of claim 27 wherein the optical element images emissions from the microplasma onto the entrance of the spectrally sensitive detector.

[c36] The spectrometer of claim 27 wherein the exit aperture of the chamber has a width that is less than one mean free path of a gaseous species of interest in the microplasma.

[c37] The spectrometer of claim 27 wherein a distance be–

tween the window and the exit aperture of the chamber is greater than one mean free path of a gaseous species of interest in the microplasma.

[c38] The spectrometer of claim 27 wherein an area of the exit aperture is less than about ten times an area of the window.

[c39] A microplasma spectrometer comprising:
a means for introducing a volume of gas to be analyzed into a chamber;
a means for generating a microplasma from the volume of gas, the microplasma having a plasma sheath volume-to-total plasma volume ratio that is greater than about 0.1;
a means for imaging emissions generated by the microplasma to an entrance of a spectrally sensitive detector; and
a means for analyzing at least one spectral region of the imaged emissions to characterize the gaseous environment.